DOCUMENT RESUME

ED 107 485 SE 018 825

AUTHOR Fletcher, Richard K., Jr.
TITLE A Study of the Relationship Between Quantitative Methods and Achievement in High School and College Science Courses.
PUB DATE 8 Nov 74
NOTE 18p.; Paper presented at the Annual Meeting of the School Science and Mathematics Association (Cincinnati, Ohio, November 1974)

EDRS PRICE MF-$0.76 HC-$1.58 PLUS POSTAGE
DESCRIPTORS *Academic Achievement; Chemistry; Educational Research; Instruction; *Integrated Activities; Literature Reviews; *Mathematics Education; Physics; *Science Education; Secondary Education; *Secondary School Science
IDENTIFIERS Research Reports

ABSTRACT

Presented is a summary of some of the available literature in which emphasis is placed on the mathematical skills required for science courses presented on the high school level. A considerable emphasis is placed on the skills required for a high school physics course. The author concludes that, in general, measures of quantitative ability are positively and significantly correlated with success in the physical sciences and that the importance of verbal ability in predicting successful achievement in both mathematics and the sciences is of primary concern. It is strongly recommended that teachers in these areas make a special effort to reinforce the learning which transpires in one discipline by showing the way it can be utilized in other areas. (Author/EB)

ED107485

A Study of the Relationship Between Quantitative Methods and Achievement in High School and College Science Courses

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION
THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY

A Paper Presented At

The Annual Convention

of The School Science and

Mathematics Association

Cincinnati, Ohio

As a Part of the Panel Discussion on

Quantitative Conceptualization in

Science and Mathematics

Dr. Richard K. Fletcher, Jr.
Associate Professor Secondary Education and Foundations
Tennessee Technological University
Cookeville, Tennessee 38501
8 November 1974

SE 018 825

INTRODUCTION

A search of the literature on a topic such as quantitative concepts or mathematical skills required for specific science courses revealed that the topic is not a new one. This paper includes a number of brief references to some of the available literature. A considerable emphasis is placed on the mathematical skills required for a high school physics course since this is the discipline where a major stress is placed on quantitative methods.

The mathematics background needed for high school physics has been a topic of discussion for many years. Historically, one of the prime reasons for placing physics at the twelfth grade level has been the belief that the student's background in mathematics is not sufficient at an earlier grade level. The results from a number of studies do not necessarily support this contention. Some writers, such as Livermore, believe that sufficient skills have been attained by the end of grade nine. (Livermore - p. 50) A presentation of representative studies is made in the following paragraphs.

PRESENTATION OF RESEARCH FINDINGS

A study was done in the 1920's to determine the mathematical content in a widely used physics text. In this investigation, Regan found 47 cases for the use of addition, 37 cases for

subtraction, 422 cases for multiplication, and 226 cases for division. He also compiled lists of mathematical concepts in algebra and geometry. (Reagan - pp. 292-299)

A more comprehensive evaluation of the mathematics needed in high school physics texts was conducted by Kilzer. From a questionnaire he determined that there were five frequently used texts for physics used in the the State of Iowa. His analysis of these five texts led him to the following conclusion:

> The mathematics needed in solving the problems of high school physics involves a considerable body of information usually taught in arithmetic, algebra and plane geometry. Not much trigonometry is needed. (Kilzer - p. 361).

A mathematics test designed for physics students was developed by Kilzer. Baily used this test to determine if drill on mathematical skills improved the ability of an experimental group in physics achievement. He found that even though less class time was available for physics instruction, the experimental group still did better in problem solving than the control group. (Baily - p. 91).

A study directed by Lockwood added more information to the bulk of knowledge regarding mathematical skill and processes needed for solving high school physics and chemistry problems.

His purpose was "to determine whether or not the assumption underlying the belief that students often avoid chemistry and physics because of the high level of difficulty of the mathematics content may be justifiable."(Lockwood - P. 56). His results based on the evaluation of seven high school chemistry and eight high school physics texts resulted in the following conclusions:

(1) Students successfully completing the first course in algebra have no valid reason for avoiding chemistry and physics because of the level of difficulty of mathematical content of these courses.

(2) The assumption underlying the belief that some students avoid chemistry and physics because of the high level of math content of these courses is not valid. (Lockwood - P. 60).

A fairly comprehensive investigation by Cain and Lee led to the following conclusions regarding mathematics preparation for the different science disciplines.

(1) The new chemistry and physics courses show only a slight increase in the use of mathematics over the traditional courses.

(2) The greatest increase in the use of mathematics from traditional to new science programs is in the use of graphs.

(3) There are numerous mathematical concepts and processes apparently useful in the science courses, both traditional and new, which are not used in these science courses.

(4) There are mathematical concepts and processes which are used in the science programs which are not

taught in the mathematics programs.

(5) The coordination of the traditional mathematics programs with the mathematical content of traditional science courses is quite poor (0.36).

(6) The coordination of new mathematics programs with the mathematical content of new science courses is higher than that for traditional programs (0.53). (Cain & Lee - pp. 712-713).

Parque found six areas of the mathematics of physics where his students were deficient. "These deficiencies lie in the areas of trigonometric functions, proportions, formulas, calculation of percentage error, fractional equations and significance figures. (Parque - P. 408).

A survey of the mathematical skills needed for solving the problems in the first four unit tests of the Project Physics course revealed that problems requiring the use of elementary algebra and arithmetic constitute 62.5% of the cases. The need for second year algebra and geometry was found for 37.5% of the cases. These values were determined by placing all test questions relating to vectors and non-linear graphs in the geometry-algebra II category. Many of these cases could be solved with scale drawings thereby reducing the amount of actual mathematical skill needed. (Fletcher - P. 57).

The discipline of chemistry also requires mathematical skills. Dence notes important major areas of mathematics where students in freshman college chemistry are sometimes weak. These include the ability to set-up word problems, the ability to generate a mathematical function from a set of experimental data; the ability to utilize logarithms; and the ability to employ the methods of elementary probability and statistics. He further notes that many students cannot correctly solve simple equations and many students who can solve the mathematical mechanics cannot set-up the problem. (Dence - pp. 287-289).

Reed presents a distribution of activities in elementary science curricula and how they are related to science and mathematics content. A total of 421 uses for mathematics was listed with measurement accounting for 154 cases and coordinate systems and graphs accounting for 80 cases. The remaining 187 cases were distributed over ten other areas. (Reed - P. 728).

Mathematics Background as a Predictor of Success in Physics and Chemistry

A common way for expressing the effectiveness of mathematical background as a predictor of success in physics and chemistry is to determine the correlation coefficient between the pre-test scores in mathematics and the post-test achievement

scores for the course. Early studies were generally done this way on the high school and the college level. Lohr calculated correlation coefficients between mathematical skill at the beginning of the year and success in physics at the end of the year. He found that for sixty students in a high school group and sixty-four students in a junior college group the correlations were each 0.44. His conclusion was that "poor mathematical skill and ability possessed by the student at the beginning of the course does not preclude the possibility of success, nor does marked ability assure success." (Lohr - pp. 395-398). He found the best correlations were between final marks and number of pages read by the student (0.68); final mark and number of problems worked (0.72); and final mark and number of hours per week studied (0.53). As a result of these correlations he said, "One big factor in success is effort." (Lohr - p. 398).

Dunlap calculated the correlation between an algebra test and physics achievement. He found the correlation to be 0.50, significant at the 0.01 level of confidence. (Dunlap - P. 303).

Studies relating to the correlation of mathematics scores and college chemistry or physics are plentiful. One of these studies by Hendricks concluded that "the best predictors of first quarter chemistry grades were the high school grade

averages and the SAT-mathematics score. (Hendricks - P. 82). He also notes that a high correlation existed between those who had taken high school advanced mathematics and those who had taken high school physics. (Hendricks - P. 83).

Brewington found "the University of Arkansas Algebra Test appeared to be a valid instrument for predicting academic success in beginning chemistry courses at the University of Arkansas." (Brewington - P. 570). Lindner found that the ACT mathematics score was a significant predictor in four of seven groups while the ACT composite score was a significant predictor in three groups of college chemistry. (Lindner - P. 1382B). Witten found that each of the four ACT subtest scores appeared as significant predictors in college physics. The ACT mathematics score was a highly significant predictor for five of the eight groups. (Witten - P. 3422B).

Bradshaw used both the ACT scores and the Cooperative Algebra Test to predict success in Engineering and Engineering Technology courses. He concluded that "the ACT composite score consistently tended to be a good predictor in each group while the effectiveness of the Cooperative Algebra Test varied considerably from group to group. (Bradshaw - P. 979A).

School grades are often compared with achievement scores in science courses. An example of such a study was one done by Hurd who devised tests in physics and ran a correlation between physics achievement and other subjects. His tests were divided into non-mathematical and mathematical with a correlation between the two being 0.80. (Hurd - P. 122). The best correlation was school marks in mathematics with his physics achievement tests, 0.73 for 83 pupils. (Hurd - P. 124). Rothman found that the ninth grade mathematics marks, a mark representing overall achievement in grade nine, and a measure of reading ability were the best predictors of success for 54 students enrolled in PSSC physics in grade ten. (Rothman - P. 101).

Naibert concluded that the most important single predictor of success in college chemistry was the average of grades attained in all mathematics courses taken. (Naibert - P. 944). Fulwood found that "both high school average and SAT Mathematics Scores were very significantly related to college physics grades." (Fulwood - P. 329A).

In a study by Scott it was concluded that "in general, grades received in high school science and mathematics are usable predictors of success in college science and mathematics." (Scott - P. 637A). Another interesting conclusion made by Scott

was that "the number of units of mathematics or science taken in high school has very little value as a predictor of success in any college science or mathematics." (Scott - P. 639A).

Fletcher compared the achievement of tenth, eleventh and twelfth grade students in the Project Physics course. He found that eleventh and twelfth grade students performed significantly better than the tenth grade group on the unit tests developed for the course. When the groups were compared while controlling IQ scores, it was determined that significant differences still existed between the different grade levels with the tenth grade group significantly lower. However, when a combination of background variables such as IQ and Cooperative Algebra Test Scores were covaried, no significant difference was found to exist. (Fletcher - pp. 93-95). The correlation between scores derived from the sum of the Algebra I and Algebra II parts of the Cooperative Algebra Test and the achievement on the unit tests for the Project Physics course was 0.66, greater than any of the other correlations. (Fletcher- p. 80). A multiple correlation of 0.78 was found to exist between the achievement on the unit tests and five predictor variables. This accounted for approximately 61 percent of the variance which can be interpreted as a measure of the predictability of success in the course. (Fletcher - p. 88).

The moderate to strong relationship which exists between mathematical or quantitative abilities and success in the physical sciences and possibly the sciences in general should play an important role in the planning of activities for these courses. Historically, there are many occasions where the development of a mathematical relationship for a physical or naturally occurring phenomenon was not possible because the mathematics had not been discovered at that point in time. This is well illustrated by Osborne (Osborne - pp. 599-604) and by Wolff (Wolff - pp. 208-213) when they describe a number of classic examples such as the development of the calculus by Sir Isaac Newton, and the limitations of the great Greek scientist Aristotle. Newton was able to accomplish an almost impossible task by developing his own mathematical tools and by tying the developments of the great works of Galileo and Kepler together. The physics of the heavens and the earth was explained with one mathematical model or form, represented as the theory of universal gravitation. Aristotle was unable to quantify such a concept as momentum because the mathematical ideas for such a process were not a part of the thinking of his time. Many other excellent examples are also mentioned by these writers and others.

Osborne adds another significant dimension to his discussion which is possibly more significant to the teaching of present day

science than one can measure. This relates to the problems of a quantitative nature which arise when teachers ask students to derive a mathematical form or formula for relationships which are discovered in inquiry oriented laboratory exercises. If a parallel to the historical development is used, one question becomes manifest, namely, how can we expect students to derive the mathematical relationship when, in fact, they may have the same problem as that faced by Aristotle? (Osborne - p. 600). This is the heart of the problem which manifests itself in almost every situation where students are asked to analyze a set of quantitative data. This problem is further amplified when one realizes that research efforts by such notable psychologists as Gagne and Ausubel and their followers have found that background pre-requisites play a most significant role in learning.

An area of concern which has been researched rather extensively is the relationship between verbal and quantitative learning. Mathematics educators are generally finding that verbal abilities are closely related to mathematical abilities. Aiken compiled an extensive search of the literature on the subject and concluded that studies, based generally on children at the intermediate level, "yielded correlations between reading ability and mathematics achievement ranging between .40 and

.86." (Aiken - p. 359) These correlations were generally higher between verbal measures and arithmetic reasoning than arithmetic fundamentals. (Aiken - p.361) This was also noted by Aiken as relating to general intelligence but not solely accounted for by that factor. (Aiken - p. 363) This is of interest since the nature of scientific problem solving is more of a reasoning process than a computational process.

The familiar phrase, transfer of training, is undoubtedly related to the problem of transferring mathematical skills to physical settings or experiments. Specific instruction relating to the skill to be transferred is recommended if performance is to be enhanced. A number of investigations have been completed which indicate that both specific training in mathematical skills by the science teacher and a heavy emphasis on vocabulary development in science and mathematics courses significantly improve problem solving efficiency. (Baily - p. 91; Aiken - p. 364-365; and Barth p. 332-33). Teachers in science and mathematics would do well to always remember that much learning is specific to a particular course and the assumption that students have already acquired a particular skill is often a false assumption.

SUMMARY AND CONCLUSIONS

In general one can conclude that measures of quantitative ability are positively and significantly correlated with success

in the physical sciences. The importance of general ability and particularly the importance of verbal ability in predicting successful achievement in both mathematics and the sciences is of primary concern. It is strongly recommended that teachers in these areas make a special effort to reinforce the learning which transpires in one discipline by showing the way it can be utilized in other areas. A close working relationship and effective purposeful planning will be needed if this is to be accomplished. As Sir Cyril Ashford so aptly stated "science asks mathematics for essential machinery; mathematics asks science for essential material; and they employ at this stage largely the same methods." (Ashford - pp. 190-191).

BIBLIOGRAPHY

Aiken, Lewis F.,Jr. "Language Factors in Learning Mathematics," Review of Educational Research, 42: 359-385, 1972.

Ashford, Sir Cyril. "The Contribution of Mathematics to Education," The Place of Mathematics in Modern Education, pp. 182-193. Eleventh Yearbook of the National Council of Teachers of Mathematics. Columbia University: Bureau of Publications,1936.

Bailey, Ralph C. "The Effects on The Achievement in Physics of Drills on the Mathematical Skills Needed in High School Physics,"School Science and Mathematics, 35:89-91, January, 1935.

Barth, Rodney J., ERIC RCS - Content Reading In Math, Journal of Reading, 17:332-333, January, 1974.

Bradshaw, Ottie Leon. "The Relationship of Selected Measures of Aptitude, Interest, and Personality to Academic Achievement in Engineering and Engineering Technology," Dissertation Abstracts. 30:979A, September-October, 1969.

Brewington, William Ivan. "A Statistical Analysis of Low Achieving and High Achieving Freshman Chemistry Students at the University of Arkansas," Dissertation Abstracts. 24:540-571, July-September, 1963.

Cain, Ralph W. and Eugene C. Lee. "An Analysis of the Relationship Between Science and Mathematics at the Secondary School Level," School Sciences and Mathematics. 63:705-713, December, 1963.

Dence, Joseph B. "The Mathematics Needed in Freshman Chemistry," Science Education, 54:287-290, 1970.

Dunlap, J. Lawrence. "Predicting Performance in High School Physics," The Physics Teacher, 4:23, January, 1966.

Fletcher, Richard K., Jr."The Effects of Grade Level and Other Factors on the Achievement in Project Physics Among High School Physics Students," Unpublished Doctoral Dissertation, The University of Virginia, Charlottesville, 1971.

Fulwood, William Edward, Jr. "Selected Factors as Related to Achievement in College Physics," Dissertation Abstracts. 27:328A-329A, July-September, 1966.

Hendricks, B. O'Neal, and others. "Selected High School Courses as Related to First Quarter Chemistry Marks," The Journal of Research in Science Teaching, 1:81-84, No. 1, 1963.

Hurd, Archer W. "Preliminary Tests as Prognostic of Final Achievement in Physics," School Science and Mathematics, 31:745-748, June, 1931.

Kilzer, L.R. "The Mathematics Needed in High School Physics," School Science and Mathematics, 29:360-362, April, 1929.

Linder, Kenneth E. "The Effects of Selected Background Variables on Success in College Chemistry," Dissertation Abstracts. 27:1382B, October-December, 1966.

Livermore, Arthur H. "Curriculum Research in Science," The Journal of Experimental Education, 37:49-55, Fall, 1968.

Lockwood, Bryce. "The Mathematical Processes Needed in Learning High School Chemistry and High School Physics," Science Education, 43: 56-60, February, 1959.

Lohr, Virgil C. "Some Factors of Success in Physics," School Science and Mathematics, 28:389-398, April, 1928.

Naibert, Zane E. "A Statistical Investigation of Factors Relating to Success in A First Course in College Chemistry," Dissertation Abstracts. 25:944, July-September, 1964.

Osborne, Alan R. "Mathematical Limitations on Scientific Creativity: A Historical Perspective," School Science and Mathematics, 69:599-604, 1969.

Parque, Richard A. "An Experimental Study to Investigate the Mathematical Needs of Students In A Traditional Physics Course," School Science and Mathematics, 64:405-408,May, 1966.

Reagan, G.W. "Mathematics Involved in Solving High School Physics Problems," School Science and Mathematics, 25:292-299, 1925.

Reed, Jack A. "Integrating the Teaching of Science and Mathematics in the Elementary School," School Science and Mathematics, 71:725-730, 1971.

Rothman, Arthur I. "Teacher Characteristics and Student Learning," Journal of Research in Science Teaching, 4:98-101, 1966.

Scott, R. L. "The Relationship Between Achievement in High School and Success in College with Reference to Science and Mathematics," Dissertation Abstracts. 27:639A, July-September, 1966.

Witten, M.H. "The Effects of Selected Background Variables on Success in College Chemistry," Dissertation Abstracts. 28:3422B, January-February, 1968.

Wolff, Georg "Mathematics As Related to Other Great Fields of Knowledge," The Place of Mathematics in Modern Education, pp. 207-244. Eleventh Yearbook of the National Council of Teachers of Mathematics. Columbia University: Bureau of Publications, 1936.